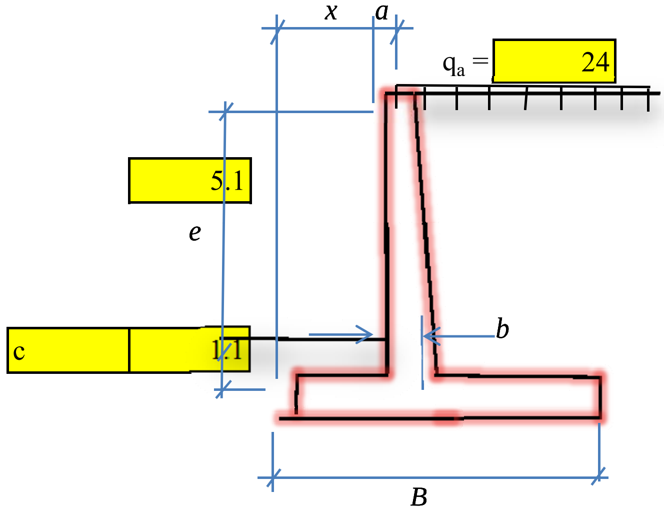
16.8.2021	6.6 m	R4

*note:the boxes in yellow should be inputed by the designer,while blue ones are computed by the progra

****====DESIGN OF A CANTILEVER RETAINING WALL===****

f_c' =	20.7	Mpa
f_y =	500	Mpa
w_s =	18.82	kN/m³
φ =	35	°
f =	0.5	
w_c =	23.6	kN/m³
q_a =	226	kPa
q_s =	24	kPa
backfill height =	3.6	m

Figure: 1

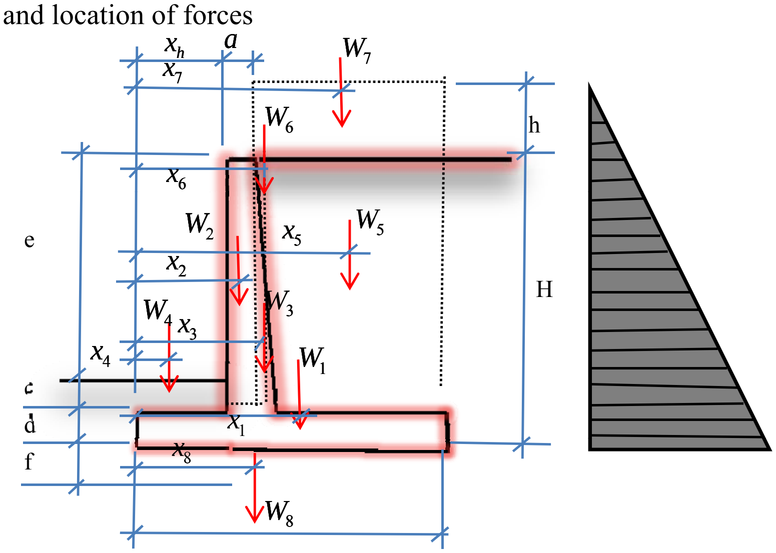


Use $W_u = 1.4DL + 1.7LL + 1.7H$

Use 16mmφ for main rebars, 12mmφ for temperature bars.

Solution:

Composite section and location of forces



Given retaining wall dimensions:

a =	0.23	m
c =	1.20	m soil thic below
e =	5.10	m
x_h =	1.00	m

Tentative dimensions:

Distances:

$x_1 = B/2$ =	2.0000	m
$x_2 = x_h + a/2$ =	1.1150	m
$x_3 = x_h + a + (b - a)/3$ =	1.2867	m
$x_4 = x_h/2$ =	0.5000	m
$x_5 = x_h + b + (B - x_h - b)/2$ =	2.7000	m

Width ftg	B =	4.00	m
th stem	b =	0.40	m
Thick ftg	d =	0.40	m
	f =	0.00	m
	g =	0.40	m
	h =	0.00	m

$x_6 = x_h + a + 2(b - a)/3 =$	1.3433	m
$x_7 = x_h + a + (B - x_h - a)/2 =$	2.6150	m
$x_8 = x_h + g/2 =$	1.2000	m
$H = d + c + e =$	6.7000	m
$h' = q_s/w_s =$	1.2752	m

Active soil pressure coefficient

$$C_{ah} = \frac{1-\sin\phi}{1+\sin\phi} = 0.27099$$

Passive soil pressure coefficient

$$C_{ph} = \frac{1+\sin\phi}{1-\sin\phi} = 3.69$$

Active soil pressure: h = 6.70 m

$$P_{ah} = \frac{1}{2}C_{ah}wh(h+2h') = 158.045 \text{ kN}$$

$$y_{ah} = \frac{h^2+3hh'}{3(h+2h')} = 2.541 \text{ m}$$

Passive soil pressure: h = 0.00 m

$$P_{ph} = \frac{1}{2}C_{ph}wh^2 = 0 \text{ kN}$$

$$y_{ph} = \frac{h}{3} = 0.000 \text{ m}$$

Check retaining wall stability:

Component weights	W_i	x_i	$RM=W_ix_i$
$W_1 = Bdw_c =$	37.76	2.0000	75.52
$W_2 = a(c + e)w_c =$	34.1964	1.1150	38.129
$W_3 = 0.5(b - a)(c + e)w_c =$	12.6378	1.2867	16.2606
$W_4 = c(x)w_s =$	22.584	0.5000	11.292
$W_5 = (B - x - b)(c + e)w_s =$	308.272	2.7000	832.333
$W_6 = 0.5(b - a)(c + e)w_s =$	10.0781	1.3433	13.5383
$W_7 = q_s(B - x - a) =$	66.48	2.6150	173.845
$W_8 = 0.5f(g + h)q_s =$	0	1.2000	0
$\Sigma W_i =$	492.008	$\Sigma W_i x_i =$	1160.92

Overturning moment: OM

$OM = P_{ah}y_{ah} =$ 401.627 kN-m

Location of resultant with respect to toe:

$$\bar{x} = \frac{RM - OM}{R_v = \sum W_i} = 1.5433 \text{ m}$$

$$e = \frac{B}{2} - \bar{x} = 0.45675 \text{ m}$$

B/3 = 1.33 m

Factor of safety against overturning:

$$FS_{overturning} = \frac{RM = \sum W_i c_i}{OM = P_{ah}y_{ah}} = 2.8905$$ > 2.00, ok!

Factor of safety against sliding:

$$FS_{sliding} = \frac{\left(fR_v = f\sum W_i\right) + P_{ph}}{P_{ah}} = 1.557$$ > 1.50, ok!

> e, Rv will fall within the middle third of the base.
No tension will occur on the foundation.

$$q_{\substack{\max \\ \min}} = \frac{R_v}{B}\left(1 \pm \frac{6e}{B^2}\right)$$

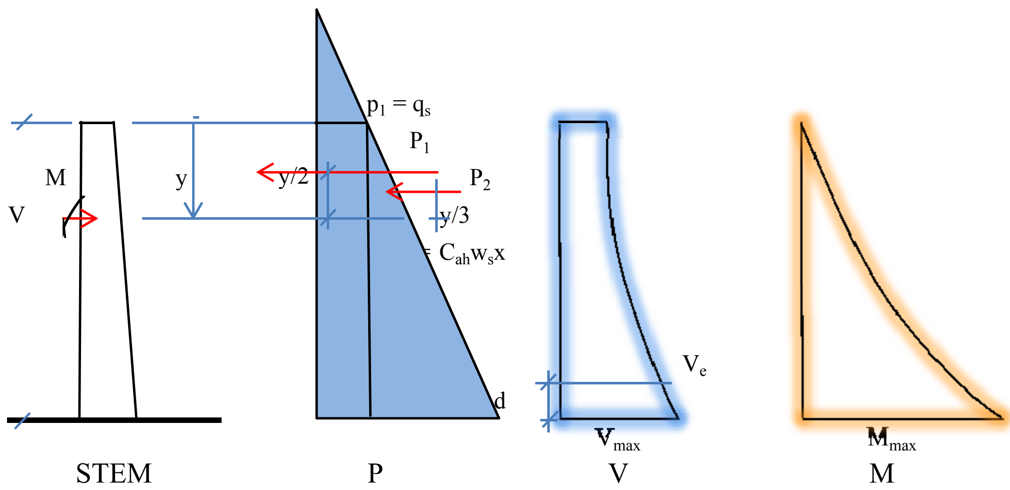
q_{max} = 144.07 kPa

q_{min} = 101.934 kPa

q_a = 226 kPa

qmax < qa, the wall is safe against soil bearing

Design of stem:



Soil pressure at level y:

$p_1 = q_s$ = 24 kPa

$p_2 = C_{ah}w_sx$ = 5.10 y kPa

Shear equation at level y:

$V_y = P_1 + P_2 = q_sy + 0.5C_{ah}w_sy^2$

$P_1 = q_sy$ = 24 y

$P_2 = 0.5Cahw_sy^2$ = 2.55 y^2

Moment equation at level y:

$M_y = P_1y_1 + P_2y_2 = q_sy^2/2 + 0.5C_{ah}w_sy^3/3$

$M_1 = P_1y_1 = q_sy^2/2$ = 12 y^2

$M_2 = P_2y_2 = 0.5C_{ah}w_sy^3/3$ = 0.85001 y^3

Level, y	V_y	V_u=1.7V_y	M_y	M_u=1.7M_y
0.00	0.000	0.000	0.000	0.000
0.50	12.638	21.484	3.106	5.281
1.00	26.550	45.135	12.850	21.845
1.50	41.738	70.954	29.869	50.777
2.00	58.200	98.940	54.800	93.160
2.50	75.938	129.094	88.281	150.078
4.00	136.800	232.560	246.400	418.881
4.50	159.638	271.384	320.457	544.776
5.50	209.138	355.535	504.420	857.513
6.00	235.801	400.861	615.601	1046.52
6.10	241.286	410.186	639.455	1087.07

Given:

E_s = 200 GPa

f_y = 500 MPa

f_c' = 20.7 MPa

f_{shear} = 0.85

$f_{flexure}$ = 0.90

D_b = 16 mmφ

D_{temp} = 12 mmφ

$S_{max} = [3t, 450]_{min}$

Compute:

$A_o = \frac{\pi}{4} D_b^{\ 2} =$ 201.1 mm²

$A_{temp} = \frac{\pi}{4} D_{temp}^{\ 2} =$ 113.097 mm²

16 mm Area 16 201.1 mm²

$\rho_{min} = \frac{1.4}{f_y} =$ 0.0028

$\rho_{max} = .75\left[\frac{.85 f_c' \beta_1}{f_y} \frac{.003E_s}{.003E_s + f_y}\right] =$ 0.01224

try d = 400 mm

$R_u = \frac{M_u / \phi}{bd^2} =$ 5.9550

$\rho = \frac{1}{\omega}\left[1 - \sqrt{1 - \frac{2\omega R_u}{f_y}}\right] = \frac{.85 f_c'}{f_y}\left[1 - \sqrt{1 - \frac{2R_u}{.85 f_c'}}\right] =$ 0.01519 not ok!-use pmin

$A_{s,flexure} = \rho bd =$ 1120.00 mm²/m

$s = \frac{1000A_o}{A_s} =$ 179.520 mm oc

$A_{s,temp} = \rho_{temp} bd = 0.002bd =$ 800 mm²/m

$s_{temp} = \frac{1000A_{temp}}{A_{s,temp}} =$ 141.372 mm oc

Check for shear:

$V_{uc} = \phi_{vc} \frac{\sqrt{f_c'}}{6} bd =$ 257.818 kN/m

At d distance from bottom of stem:

y = 1.5 m

$V_{ud} = 1.7(19.2y + 3.13667y^2) =$ 60.958 kN/m

At 3.00 m

Try d = 300 mm

0	230
3.6	350
3	330

$R_u = \frac{M_u / \phi}{bd^2} =$ 6.72564

$\rho = \frac{1}{\omega}\left[1 - \sqrt{1 - \frac{2\omega R_u}{f_y}}\right] = \frac{.85 f_c'}{f_y}\left[1 - \sqrt{1 - \frac{2R_u}{.85 f_c'}}\right] =$ 0.01811 not ok!-use pmin

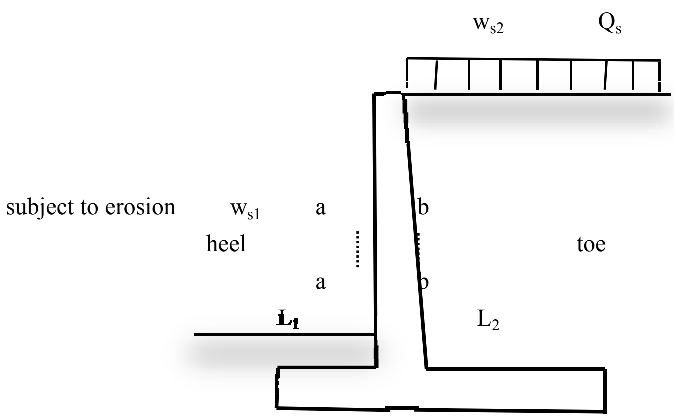
$A_{s,flexure} = \rho bd =$ 840.00 mm²/m

$s = \frac{1000A_o}{A_s} =$ 239.359 mm oc

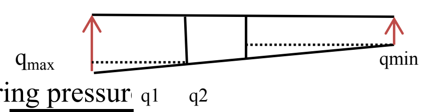
$A_{s,temp} = \rho_{temp}bd = 0.002bd =$ 600 mm²/m

$$s_{temp} = \frac{1000A_{temp}}{A_{s,temp}} = \quad 188.496 \text{ mm oc}$$

Design of heel and toe:



Use load factor:
1.4 for DL
1.7 for ll and service load bearing pressur



q_{max} x 1.7 =	244.919	kPa		e =	0.45675	m
q_{min} x 1.7 =	173.288	kPa		At a, x =B/2 - x_h =	1	m
w_{s1} = 1.4(w_s)c =	31.6176	kPa		q_1 =	280.734	kPa
w_{s2} = 1.4(w_s)(c + e) =	165.992	kPa		At b, x = [B/2 - (x_h + b)] =	0.6	m
q_s x 1.7 =	40.8	kPa		q_2 =	252.082	
W_c = 1.4(w_c)d =	13.216	kPa		$L_1 = x_h$ =	1.00	m
				L_2 = B - (x_h + b) =	2.60	m

$V_a = .5(q_{max} - q_1)L_1 + q_1L_1 - (w_{s1}=0)L_1 - W_cL_1 =$	249.611	kN
$M_a = (q_{max} - q_1)L_1^2/3 + (q_1 - (w_{s1} = 0) - W_c)L_1^2/2 =$	121.821	kN-m
$V_b = (.5(q_2 - q_{min})L2 = 0) + [(q_{min} = 0) - w_{s2} - w_c - q_s]L_2 =$	-572.022	kN
$M_b = [(q_2 - q_{min}) = 0]L_2^2/6 + [(q_{min} = 0) - w_{s2} - w_c - q_a]L_2^2/2 =$	-743.628	kN-m

w_{s1} is taken equal to zero due to erosion of top soil at the heel, the expected worst condition of loading.
At the toe, the worst condition of loading is when the wall is at empending action to overturn, soil bearin;
at the heel is assumed to be zero.

At Heel:

try d = 400 mm

$$R_u = \frac{M_u/\phi}{bd^2} = 0.8460$$

$$\rho = \frac{1}{\omega}\left[1-\sqrt{1-\frac{2\omega R_u}{f_y}}\right] = \frac{.85f_c'}{f_y}\left[1-\sqrt{1-\frac{2R_u}{.85f_c'}}\right] = 0.0017$$ **not ok!-use pmin**

$A_{s,flexure} = \rho bd =$ 1120.00 mm²/m

$$s = \frac{1000A_o}{A_s} = 179.52$$ mm oc   101.013

$A_{s,temp} = \rho_{temp}bd = 0.002bd =$ 800 mm²/m

$$s_{temp} = \frac{1000A_{temp}}{A_{s,temp}} = 141.37$$ mm oc

Check for shear:

$$V_{uc} = \phi_{vc}\frac{\sqrt{f_c'}}{6}bd = 257.818$$ kN/m   **> Va, safe**

At Toe:

try d = 400 mm

$$R_u = \frac{M_u/\phi}{bd^2} = 5.16409$$

$$\rho = \frac{1}{\omega}\left[1-\sqrt{1-\frac{2\omega R_u}{f_y}}\right] = \frac{.85f_c'}{f_y}\left[1-\sqrt{1-\frac{2R_u}{.85f_c'}}\right] = 0.01257$$ **not ok!-use pmin**

$A_{s,flexure} = \rho bd =$ 1120 mm²/m

$$s = \frac{1000A_o}{A_s} = 179.52$$ mm oc

$A_{s,temp} = \rho_{temp}bd = 0.002bd =$ 800 mm²/m

$$s_{temp} = \frac{1000A_{temp}}{A_{s,temp}} = 141.372$$ mm oc

Check for shear:

$$V_{uc} = \phi_{vc}\frac{\sqrt{f_c'}}{6}bd = 257.818$$ kN/m   **> Va, safe**